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Effects of Atropine/2-PAM Chloride, Heat and Chemical Protective Clothing on Visual Performance.

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Visual acuity, phoria, stereopsis and contrast sensitivity were assessed over six hours of continued exposure to combinations of atropine (2 mg) and 2-PAM chloride (600 mg), severe heat/humidity (95°F/60%RH), and wearing either the US Army battle dress uniform (BDU) or impermeable chemical protective clothing (MOPP-IV). Subjects were able to complete all six hours of testing under severe heat when wearing BDU's, but only lasted two hours under the same severe heat when wearing MOPP-IV. Acuity and phoria were significantly impaired by drug in the BDU conditions. Acuity, phoria and stereopsis were all significantly impaired by heat, drug and continued exposure under MOPP-IV. Acuity was significantly impaired by drug even during the first two hours of heat exposure in MOPP-IV. Contrast sensitivity was impaired mainly by continued heat exposure in MOPP-IV.

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Title:
Effects of Atropine/2-PAM Chloride, Heat and Chemical Protective Clothing on Visual Performance

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Drug-Heat Effects on Vision

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Abstract

Visual acuity, phoria, stereopsis and contrast sensitivity were assessed over six hours of continued exposure to combinations of atropine (2 mg) and 2-PAM chloride (600 mg), severe heat/humidity (95°F/60%RH), and wearing either the US Army battle dress uniform (BDU) or impermeable chemical protective clothing (MOPP-IV). Subjects were able to complete all six hours of testing under severe heat when wearing BDU's, but only lasted two hours under the same severe heat when wearing MOPP-IV. Acuity and phoria were significantly impaired by drug in the BDU conditions. Acuity, phoria and stereopsis were all significantly impaired by heat, drug and continued exposure under MOPP-IV. Acuity was significantly impaired by drug even during the first two hours of heat exposure in MOPP-IV. Contrast sensitivity was impaired mainly by continued heat exposure in MOPP-IV.

Index Terms:

Vision

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Heat stress

Chemical protection

Visual acuity

Contrast sensitivity

Introduction

The possibility of chemical weapons being used in future warfare requires that both effective antidotes and protective clothing be available for military personnel. The current antidote for nerve agents is 2 mg atropine sulfate (atropine) paired with 600 mg pralidoxime chloride (2-PAM), injected intra-muscularly. Although these drugs are effective antidotes, they also generate side-effects which can adversely affect certain aspects of behavior.

The major physiological reactions to atropine alone have been identified (2,7,15). The physiological effects of 2-PAM alone and in combination with atropine have also been studied (10,19), but to a somewhat lesser degree. The effects of these drugs on psychological, perceptual and cognitive behavior are less clear, although some performance-oriented studies have been reported (16,18). Atropine has been shown to significantly influence aspects of visual behavior, particularly acuity, accommodation, oculo-motor activity and dark adaptation (11,17,20). Other reported visual reactions to atropine are mydriasis, cycloplegia and reduced contrast sensitivity (1,8). Although the joint effects of these drugs when taken together have been partially explored (9), more information about their combined action and/or potentiation is essential because of their paired use as the standard nerve agent antidote.

The effects of heat exposure combining with these drug effects are another military consideration, since many potential tactical areas are in desert or tropic regions. Heat exposure will have further debilitating effects when troops also have to wear chemical protective clothing, termed the Mission Oriented Protective Posture (MOPP) system. This ensemble is based on a modular concept which involves increasing levels of encapsulation (MOPP-I, -II, -III, -IV) to achieve greater degrees of protection. At MOPP-IV involving

total encapsulation, trapped moisture inside the ensemble becomes a stressor and also impairs performance. These problems intensify when MOPP-IV is worn in a hot environment.

Situations could also arise where atropine/2-PAM would be used by troops while also wearing MOPP-IV in the heat (e.g., surprise attacks, damage to MOPP-IV clothing, or premature antidote administration), leading to increased heat/humidity stress combined with effects of drug antidote. In other scenarios, atropine/2-PAM could be used by troops in the heat wearing only the battle dress uniform (BDU). Although some information is available on the effects of these drugs combined with heat exposure (4,5,6,13,14), systematic data are needed to assess the relative performance capabilities of military personnel under the various combinations of these circumstances.

In a research project to address these issues, Kobrick, Johnson and McMenemy (12) investigated the effects of heat exposure, wearing of both the BDU and MOPP-IV ensembles, and standard atropine/2-PAM dosage on the performance of a variety of psychological, sensory-perceptual and psychomotor tasks, as well as on symptomatic and subjective reactions. The overall project consisted of two separate studies which were identical except that in one study the subjects wore the BDU ensemble, while in the other study the subjects wore MOPP-IV. This paper summarizes the effects observed on selected indices of visual performance; specifically, acuity, phoria, stereopsis, and contrast sensitivity.

Study 1. Effects of Atropine/2-PAM and Heat Exposure on Visual Performance While Wearing the BDU Ensemble

Method

Subjects

Fifteen male soldier volunteers, ages 18-32, were screened medically and tested for normal correctible visual acuity (20/20 Snellen), phoria and stereopsis. They were briefed on the nature and potential hazards of the study, and then read and signed a volunteer agreement of informed consent.

Procedure

The subjects were trained intensively approximately six hours daily for five consecutive days on a group of performance tasks related to military activities, among which were the visual measures discussed in this paper. Thereafter, they performed the tasks on four separate test days, each day corresponding to one of the following experimental test conditions: (1) control (saline placebo; 70°F, 30% RH); (2) drug only (2 mg atropine, 600 mg 2-PAM; 70°F, 30% RH); (3) ambient heat only (saline placebo; 95°F, 60% RH); (4) drug and ambient heat (2 mg atropine, 600 mg 2-PAM ; 95°F, 60% RH). On each test day, subjects received either the assigned combination of atropine and 2-PAM, or equivalent volumes of saline placebo, injected into the thigh muscle by 22-gauge syringes. Atropine was administered by one injection, but since 2-PAM causes discomfort at the injection site the required 600-mg dose was divided into two 300-mg units, one injected into the thigh muscle of each leg. Drug conditions were assigned on a double-blind basis by an individual who was not involved in the study; however, for safety reasons, a medical monitor presiding over the study knew the identities of both drug and placebo subjects. Test days were separated by at least three days off to insure adequate recovery from the preceding drug conditions. Testing commenced each day approximately 30 minutes after drug administration.

All subjects were targeted to complete three performances of the total cycle of tasks on each testing day, and continued to perform until the point

of either voluntary withdrawal or mandatory removal by the medical monitor for exceeding medical safety criteria (pulse rate exceeding 160 bpm for five minutes continuously, and/or, rectal core temperature in excess of 39°C. (102.2°F)). The three testing cycles were begun at standard 2-hour intervals in order to maintain uniform overall daily periods of exposure to the heat. Subjects were allowed to drink water ad lib from standard military canteens; however, lunch and snacks were omitted. In addition to the performance tasks, subjects completed self-rating inventories of subjective reactions administered periodically during the course of each experimental session.

Visual acuity, phoria and stereopsis were measured with a Bausch and Lomb Ortho-Rater. Visual acuity, defined as the ability to detect fine visual detail at both near (as in reading) and far (as in automobile driving) viewing distances were separately obtained both monocularly and binocularly. Subjects viewed series of successively smaller checkerboard test patterns corresponding to decreasing magnitudes of subtended visual angle, and selected the smallest resolvable pattern in each case.

Phoria, defined as the state of binocular alignment of the visual axes of both eyes, was measured separately for both lateral and vertical planes of view. For each plane, subjects binocularly viewed two reticle targets presented separately to each eye, and noted their point of apparent intersection as an index of phoric balance.

Stereopsis, defined as perception of apparent relative distance based on small amounts of retinal image disparity, was measured binocularly. Subjects viewed a series of numerals, each seen against a circular background. Each numeral in the series differed in slight but successively smaller magnitudes of depth from its background, and subjects selected the last numeral which

appeared to "stand out".

Contrast sensitivity, defined as the ability to discern subtle brightness differences among alternating shades of gray, was measured with the Nicolet Optronics CS2000 system. Subjects viewed a series of striped patterns on a video screen which represented selected frequencies of alternation of different shades of gray (spatial frequencies), and adjusted each pattern to the lowest brightness at which a striped pattern could be seen.

Results

Visual acuity

The series of checkerboard targets used in the Ortho-Rater acuity test plates subtend visual angles which diminish along a curvilinear function of decreasing visual angle, thereby providing scales of increasing difficulty of resolution. The acuity threshold function curve is shown in Figure 1.

Insert Figure 1 about here

Because of this arrangement, the scores obtained with the test are not linearly additive. In order to linearize the visual acuity data to conform to the statistical requirements of analysis of variance, the individual measures were first converted to equivalent units in degrees of visual angle (DVA) subtended at the retina, and were then transformed to reciprocals. Group means of these individual reciprocal values were then calculated for the various test conditions and are summarized in Table 1, along with results for the phoria and stereopsis measures, to be described.

Insert Table 1 about here

Three-way (drug x heat x cycle) analyses of variance for repeated measures were then performed separately on the individual reciprocal acuity values for right monocular, left monocular and binocular vision at both near and far viewing distances, respectively. These analyses showed significant main effects due to drug for far left acuity ($F = 9.09$, $P = .009$) (placebo group mean = .94 DVA; drug group mean = .98 DVA), near left acuity ($F = 8.45$, $P = .01$) (placebo group mean = .92 DVA; drug group mean = .99 DVA), and near binocular acuity ($F = 4.88$, $P = .04$) (placebo group mean = 1.02 DVA; drug group mean = 1.06 DVA). There were no significant main effects due either to heat or to continued exposure (cycle). Significant first-order drug x heat interactions were also found for near left acuity ($F = 12.65$, $P = .003$) and near binocular acuity ($F = 3.49$, $P = .05$). No other significant main effects or interactions were found.

Phoria

The lateral and vertical phoria scores were first converted to equivalent prism diopter (PD) units, and group means were then calculated from the individual subject scores. These values are also summarized in Table 1. Three-way analyses of variance for repeated measures were then separately performed on the individual lateral and vertical phoria scores. A highly significant main effect due to drug was found for far lateral phoria ($F = 30.06$, $P = .0002$) (placebo group mean = 1.03 PD; drug group mean = 2.37 PD). Significant drug x heat first-order interactions were also found for near lateral phoria ($F = 5.51$, $P = .03$) and near vertical phoria ($F = 4.36$, $P =$

.05), as well as a drug x cycle interaction for near vertical phoria (F = 3.05, P = .05). No other significant main effects or interactions were found.

Stereopsis

The stereopsis scores were first converted to their equivalent values of threshold target image disparities in seconds of arc-degrees. Group means calculated from the individual measures can also be seen in Table 1. A three-way analysis of variance for repeated measures performed on the individual scores showed no significant main effects or interactions due to drug, heat or cycle.

Contrast sensitivity

The Nicolet test provides automatic calculation of the log contrast sensitivity index for each threshold setting, based on the equation: $Log_{10}[Luminance_{max}+Luminance_{min}/(Luminance_{max}-Luminance_{min})]$ (21). Separate three-way analyses of variance for repeated measures were conducted on the individual contrast sensitivity indices for each spatial frequency tested by the system (1, 3, 6, 11.4, 22.8 cycles/degree). No significant main effects or simple interactions for drug, temperature or testing cycle were found for any of the spatial frequencies tested.

The results of this study indicated significant overall impairment of some aspects of both visual acuity and phoria due to atropine/2-PAM administration, but not to heat exposure. However, the impairments noted have no common pattern, and therefore are probably not specifically meaningful in themselves. Nevertheless, the data do indicate a general influence of atropine/2-PAM on ocular control, and reflect effects which have long been noted in the vision literature for atropine alone. Heat exposure,

on the other hand, had no effect by itself on visual performance, and only exerted an influence in interaction with the drug effect.

Study 2. Effects of Atropine/2-PAM and Heat Exposure on Visual Performance While Wearing the MOPP-IV Ensemble

Method

Subjects

Eight male soldier volunteers, ages 18-22, who had not participated in Study 1, were medically screened and tested for normal vision. They were briefed about the study, and then signed a volunteer agreement of informed consent.

Procedure

Study 2 was conducted in an identical manner to Study 1, except that during both training and testing the subjects wore the complete MOPP-IV ensemble (including charcoal impregnated jacket and trousers, rubber overboots, mask, hood and rubber gloves), over the BDU system. Also, the ambient temperature of the no-heat control condition was reduced to 55°F/30%RH (from 70°F/30%RH used in Study 1) in order to compensate for the additional heat load caused by wearing the MOPP-IV system.

Results

The overall stress effects of the test conditions involving 95°F in Study 2 proved so severe that only one subject was able to begin and to perform part of Cycle 2; no one was able to begin Cycle 3. These incomplete performances resulted in missing data blocks in Cycles 2 and 3. In order to apply analysis of variance techniques to the overall data of Study 2, it was therefore necessary to substitute realistic scores for the missing data values. For data analysis purposes, subjects were scored as having the

minimal, or poorest possible score for each test administration which was missed, and the group averages reflect this scoring procedure. Admittedly, it is difficult to justify making a distinction between the performance of subjects who are removed from a stressful situation because of medical reasons and that of subjects who do not perform for other reasons, but are still present. However, we feel that the procedure used here provides a realistic way to adjust the data to compensate for this type of situation.

Visual acuity

The visual acuity measures for right monocular, left monocular and binocular viewing at both near and far viewing distances were converted to equivalent units of visual angle, and then were linearized by transformation to reciprocals, as with the data of Study 1. Group means of the individual reciprocal values are shown as part of Table 2, along with the results for the phoria and stereopsis measures.

Insert Table 2 about here

Separate three-way (drug x heat x cycle) analyses of variance were then conducted on the reciprocal visual acuity values. The results of these analyses are summarized in Table 3, along with results of analyses of the phoria and stereopsis measures to be discussed below.

Insert Table 3 about here

It can be seen in Table 3 that significant main effects for both heat and cycle, as well as significant first-order heat x cycle interactions, were

found for all acuity measures. Also, significant main effects for drug were obtained for all acuity measures except far binocular viewing.

Phoria

The lateral and vertical phoria scores were first converted to prism diopter units, and group means were calculated from the individual subject scores. These group means are also shown in Table 2. Separate within-subjects analyses of variance were then conducted for both near and far lateral and vertical phoria, based on the individual subject prism diopter values. The resulting main effects and significance levels are shown in Table 3. It can be seen that significant main effects for both heat and cycle were obtained for all phoria measures. Significant first-order heat x cycle interactions were also obtained for all measures except near lateral phoria. However, a significant main effect due to drug was obtained only for far vertical phoria.

Stereopsis

The stereopsis scores were first converted to equivalent arc-degree values, and group means were then calculated from the individual scores. These values can also be seen in Table 2. Separate within-subjects analyses of variance for repeated measures were then conducted on the arc-degree values, and the resulting main effects and significance levels are also summarized in Table 3. Significant main effects were again obtained for heat, cycle and the first-order interaction of heat x cycle.

Contrast sensitivity

The contrast sensitivity indices for each threshold setting were derived as described above for Study 1, and the individual scores for each spatial frequency (1, 3, 6, 11.4, 22.8 cycles per degree) were then analyzed by

separate within-subjects analyses of variance. The results of these analyses are summarized in Table 4. The overall group mean contrast sensitivity indices for spatial frequencies in each test condition are also shown.

Insert Table 4 about here

It can be seen in Table 4 that highly significant main effects were obtained for heat and continued exposure (cycle) at all spatial frequencies, except for the second of two tests at 5 C/D. The effects of drug were significant at only two spatial frequencies (5 C/D (1) and 6 C/D (2)), which in themselves probably have little meaning in the context of the overall effect of drug on spatial frequencies. Note that there was only one significant interaction among the main effects (H x C for 6 C/D (1)). Bar charts of the group mean spatial frequencies for drug, heat and cycles are shown as Figures 2-4.

Insert Figures 2-4 about here

It can be seen in Figures 3 and 4 that heat and continued exposure (cycles) systematically impaired contrast sensitivity at all spatial frequencies. Figure 2 indicates a similar but somewhat less systematic impairment, in that all spatial frequencies except 1 and 5 cycles per degree were involved.

Separate analyses of variance of the data for Cycle 1 alone were also performed to augment the main findings by reflecting the performance capabilities of the subjects during the period prior to their removal from the study. The significant findings of these analyses are summarized in Table 5 for acuity, phoria and contrast sensitivity; stereopsis was unchanged, and,

therefore, is not included.

Insert Table 5 about here

A comparison of Table 5 with Tables 3 and 4 indicates lesser overall visual impairment during Cycle 1 than was found for the overall Study 2 analysis. Visual acuity in Cycle 1 was affected only by drug, along with one measure each of phoria and contrast sensitivity, while heat affected one measure of phoria and three spatial frequencies of contrast sensitivity. These results contrast with the comprehensive impairments by drug, heat and cycle shown in the overall analysis.

Discussion and Conclusions

The results of Study 1 clearly indicate that even under the relatively moderate heat stress of the BDU conditions compared to the severe heat stress of the MOPP-IV conditions, a single dose of atropine/2-PAM still had a significant effect on aspects of both visual acuity and phoria. These impairments are consistent with known ophthalmic effects of atropine, principally blurring of vision through cycloplegia and consequent loss of lens accommodation, as well as mydriasis leading to ocular defocusing through pupillary dilatation. The results also realistically demonstrate the known effects of atropine in altering ocular muscle balance (3). However, the specific aspects of acuity and phoria which were affected are probably not as meaningful in themselves as were the overall effects of the drugs on these visual functions in general.

In Study 2, since all but one of the subjects were incapacitated by severe heat stress after Cycle 1 at 95°F/60%RH in MOPP-IV, it is impossible to assess

their absolute visual capabilities beyond that point. Nevertheless, the overall Study 2 statistical analysis realistically reflects the expectable operational capabilities of troops under such conditions. With this in mind, it is meaningful to note that virtually all of the visual attributes tested were profoundly affected by all three major study variables (drug, heat and continued exposure). Although phoria and stereopsis were influenced primarily by extended exposure to heat, both monocular and binocular visual acuity showed significant impairment by drug, heat, and cycle as well as by their major interactions. The strong drug effect found for visual acuity was not seen for the other visual functions, since they showed no differences of any consequence between the drug and placebo conditions under the severe heat stress of the MOPP-IV conditions. Although the effects on phoria were not systematic, they were highly statistically significant under both BDU and MOPP-IV conditions. Contrast sensitivity showed only a moderate effect of drug, but was also affected by both heat and cycle at all spatial frequencies under MOPP-IV, although not under the BDU conditions. Thus, heat stress was the major overall impairing factor, although under the lesser heat stress of the BDU conditions a strong drug effect on acuity and phoria was still observed.

The relative contributions of atropine versus 2-PAM to the total effects observed cannot be specifically established by our data, since the drugs were given together. However, considering the known effects of atropine versus those of 2-PAM on the visual system, the present results are most likely due to the action of atropine. The drug influence on visual performance is discernible in both the BDU and MOPP-IV studies when the subjects were still functional. On the other hand, heat had a more fundamental overall effect by

curtailing the duration of performance, even though it had no appreciable influence on vision per se.

It is curious that in the BDU conditions neither stereopsis nor contrast sensitivity were affected by the drug or heat conditions, since these measures tap very sensitive aspects of visual performance and should thereby be vulnerable to stress. This reasoning should hold especially for contrast sensitivity based on distinction of subtle differences in levels of brightness, in comparison with visual acuity which involves only black-white resolution at high brightness. Unfortunately, the present data cannot explain why the more discriminable visual tasks were impaired while those requiring subtler visual distinctions were unaffected.

In summary, acuity and phoria were significantly impaired by drug in the BDU conditions, and acuity, phoria and stereopsis were all significantly impaired by heat, drug and continued exposure under MOPP-IV. Acuity was significantly impaired by drug even during the first two hours of heat exposure in MOPP-IV. Contrast sensitivity was impaired mainly by continued heat exposure in MOPP-IV.

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TABLE 1

SUMMARY OF GROUP MEANS OF ORTHO-RATER
SCORES FOR SUBJECTS WEARING THE BATTLE DRESS UNIFORM

Measure	70°/Pl.	70°/Dr.	95°/Pl.	95°/Dr.
CYCLE 1				
Far Acuity				
Biroc.	1.069	1.055	1.102	1.027
Right	1.008	1.002	1.022	.974
Left	.961	.954	1.008	.955
Near Acuity				
Binoc.	1.089	1.042	1.096	1.035
Right	1.022	.974	1.008	.962
Left	1.021	.995	1.021	.994
Far Vert. Phor.	.291	.303	.325	.325
Near Vert. Phor.	.391	.391	.325	.435
Far Lat. Phor.	.933	1.000	.732	.867
Near Lat. Phor.	-3.300	-0.500	-2.100	-.300
Stereopsis	109.670	133.360	158.760	91.030
CYCLE 2				
Far Acuity				
Binoc.	1.082	1.048	1.082	1.048
Right	.988	1.001	.995	1.002
Left	.980	.941	.987	.928
Near Acuity				
Binoc.	1.082	1.035	1.137	1.016
Right	.988	.947	1.015	.935
Left	1.028	1.001	1.035	.927
Far Vert. Phor.	.303	.325	.325	.303
Near Vert. Phor.	.369	.336	.325	.402
Far Lat. Phor.	.801	1.133	.799	1.399
Near Lat. Phor.	-3.500	-1.400	-1.300	.600
Stereopsis	113.540	132.340	132.940	113.890
CYCLE 3				
Far Acuity				
Binoc.	1.076	1.041	1.075	1.041
Right	1.009	.988	1.008	.968
Left	.988	.941	1.021	.954
Near Acuity	1.059	1.092	1.012	1.127
Far Vert. Phor.	.303	.325	.325	.303
Near Vert. Phor.	.380	.336	.325	.347
Far Lat. Phor.	1.066	1.266	.999	1.267
Stereopsis	133.290	133.690	137.870	91.560

TABLE 2

SUMMARY OF GROUP MEAN ORTHO-RATER SCORES
FOR SUBJECTS WEARING MOPP-IV CHEMICAL PROTECTIVE CLOTHING

Measure	55°/Pl.	55°/Dr.	95°/Pl.	95°/Dr.
CYCLE 1				
Far Acuity				
Binoc.	.990	1.001	1.069	1.066
Right	.976	1.044	.980	1.095
Left	.916	.979	.924	1.009
Near Acuity				
Binoc.	1.152	2.331	1.125	1.258
Right	1.016	1.229	1.071	1.254
Left	.949	1.062	.976	1.244
Far Vert. Phor.	.170	.252	.211	.439
Near Vert. Phor.	.170	.294	.252	.252
Far Lat. Phor.	2.329	2.120	1.537	2.371
Near Lat. Phor.	3.375	2.625	2.812	3.375
Stereopsis	58.100	57.060	24.180	31.760
CYCLE 2				
Far Acuity				
Binoc.	1.074	.994	1.250	1.365
Right	1.029	1.052	1.541	1.875
Left	.965	.982	1.215	1.355
Near Acuity				
Binoc.	1.055	1.098	5.521	8.854
Right	.989	1.111	1.510	1.875
Left	1.059	1.144	1.718	2.291
Far Vert. Phor.	.252	.211	.667	.896
Near Vert. Phor.	.211	.211	.376	.459
Far Lat. Phor.	1.537	1.787	3.955	4.955
Near Lat Phor.	2.625	4.312	4.312	6.000
Stereopsis	60.760	56.890	195.010	317.960
CYCLE 3				
Far Acuity				
Binoc.	1.085	1.087	1.430	1.430
Right	.980	1.121	2.000	2.000
Left	.966	1.005	1.430	1.430
Near Acuity				
Binoc.	1.015	2.345	10.000	10.000
Right	1.036	1.238	2.000	2.000
Left	1.022	1.214	2.500	2.500
Far Vert. Phor.	.211	.356	1.000	1.000
Near Vert. Phor.	.252	.335	.500	.500
Far Lat. Phor.	2.579	2.246	5.330	5.330
Near Lat. Phor.	3.375	4.125	6.000	6.000
Stereopsis	60.350	62.900	362.00	362.000

TABLE 3

SUMMARY OF ANALYSES OF VARIANCE OF ORTHO-RATER MEASURES
FOR SUBJECTS WEARING MOPP-IV CHEMICAL PROTECTIVE CLOTHING

TEST	DRUG		TEMP		CYCLE		D x T	
	F	P	F	P	F	P	F	P
Far Acuity								
Binoc.	0.08	0.77	30.09	0.000	17.27	0.004	1.14	0.32
Right	6.68	0.03	66.47	0.000	43.01	0.001	0.97	0.36
Left	8.91	0.02	94.91	0.000	35.08	0.001	0.42	0.54
Near Acuity								
Binoc.	13.59	0.008	179.04	0.000	62.26	0.000	0.12	0.73
Right	18.66	0.004	62.05	0.000	16.05	0.005	0.003	0.91
Left	6.89	0.03	91.80	0.000	279.61	0.000	1.47	0.26
Phoria								
Far Vert.	11.56	0.01	76.87	0.000	29.59	0.001	1.61	0.24
Near Vert.	2.88	0.13	39.07	0.001	12.71	0.008	2.03	0.19
Far Lat.	1.00	0.35	25.33	0.002	26.79	0.002	2.89	0.13
Near Lat.	2.64	0.14	9.75	0.02	32.71	0.001	0.04	0.82
Stereopsis	1.51	0.26	28.04	0.001	12.53	0.008	3.51	0.10

TEST	D x C		T x C		D x T x C	
	F	P	F	P	F	P
Far Acuity						
Binoc.	0.04	0.95	3.60	0.09	2.51	0.16
Right	0.34	0.72	19.14	0.003	2.20	0.19
Left	1.62	0.27	21.41	0.002	0.86	0.47
Near Acuity						
Binoc.	0.41	0.68	52.68	0.000	3.95	0.08
Right	1.55	0.29	20.74	0.003	4.58	0.06
Left	3.95	0.08	17.71	0.004	5.11	0.05
Phoria						
Far Vert.	0.53	0.61	34.24	0.001	6.95	0.03
Near Vert.	0.04	0.95	8.10	0.02	1.23	0.36
Far Lat.	0.93	0.45	40.42	0.001	0.96	0.87
Near Lat.	3.86	0.08	3.04	0.12	1.36	0.32
Stereopsis	4.02	0.08	19.22	0.003	1.94	0.22

TABLE 4

SUMMARY OF ANALYSES OF VARIANCE AND GROUP MEANS OF CONTRAST SENSITIVITY MEASURES FOR SUBJECTS WEARING MOPP-IV CHEMICAL PROTECTIVE CLOTHING

	DRUG		HEAT		CYCLE		D x H	
	F	P	F	P	F	P	F	P
Spat. Freq.								
1 C/D	.62	.46	11.78	.01	4.49	.03	2.14	.18
3 C/D	.09	.76	6.37	.04	12.31	.001	.06	.80
5 C/D (1)	7.10	.03	16.06	.005	10.96	.002	.25	.63
5 C/D (2)	.31	.60	.55	.45	1.92	.18	.04	.83
6 C/D (1)	1.26	.30	20.92	.003	15.64	.0004	.25	.85
6 C/D (2)	6.09	.04	51.08	.0004	13.39	.0008	2.54	.15
11.4 C/D	.86	.39	10.53	.01	13.69	.0007	3.52	.10
22.8 C/D	2.02	.20	11.00	.01	4.91	.02	1.03	.34

	D x C		H x C		D x H x C	
	F	P	F	P	F	P
Spat. Freq.						
1 C/D	.14	.86	1.35	.29	1.41	.27
3 C/D	.71	.51	3.25	.07	2.46	.12
5 C/D (1)	1.75	.21	1.42	.27	.21	.81
5 C/D (2)	.66	.53	1.25	.32	.02	.97
6 C/D (1)	.18	.83	4.35	.03	.37	.70
6 C/D (2)	.83	.46	2.66	.10	2.37	.13
11.4 C/D	.29	.76	1.78	.20	3.42	.06
22.8 C/D	1.56	.24	1.73	.21	.45	.65

GROUP MEAN CONTRAST SENSITIVITY MEASURES

	PLACEBO	DRUG	NO HEAT	HEAT	CYCLE 1	CYCLE 2	CYCLE 3
1 C/D	117.29	126.03	157.06	86.27	146.56	113.90	104.54
3 C/D	302.67	293.26	352.71	243.22	414.78	272.52	206.61
5 C/D (1)	22.09	26.29	30.89	17.49	29.47	23.90	19.20
5 C/D (2)	30.44	34.60	35.56	29.48	36.27	40.19	21.10
6 C/D (1)	338.51	280.81	391.70	227.62	432.52	275.82	220.63
6 C/D (2)	325.13	237.88	384.87	178.13	391.92	265.10	187.49
11.4 C/D	205.28	167.78	235.89	137.18	267.07	186.27	106.26
22.8 C/D	67.46	49.80	79.97	37.28	79.81	56.61	39.46

TABLE 5

SUMMARY OF ANALYSES OF VARIANCE OF VISUAL ACUITY, PHORIA AND CONTRAST SENSITIVITY MEASURES DURING CYCLE 1 FOR SUBJECTS WEARING CHEMICAL PROTECTIVE CLOTHING

TEST	DRUG		TEMP		D x T	
	F	P	F	P	F	P
Far Acuity						
Binoc.						
Right						
Left	8.88	.02				
Near Acuity						
Binoc.						
Right	13.88	.007				
Left	4.86	.06				
Phoria						
Far Vert.	9.00	.02	7.00	.03		
Near Vert.						
Far Lat.						
Near Lat.						
Contrast Sensitivity						
1 C/D			4.82	.06		
3 C/D						
5 C/D (1)	5.70	.05	8.98	.02		
5 C/D (2)						
6 C/D (1)						
6 C/D (2)						
11.4 C/D					4.97	.06
22.8 C/D						

Figure Captions

Figure 1. Threshold function curve for the target series used in the Ortho-Rater visual acuity test plates

Figure 2. Overall group means by spatial frequency for drug averaged across heat and cycles

Figure 3. Overall group means by spatial frequency for heat averaged across drug and cycles

Figure 4. Overall group means by spatial frequency for separate cycles averaged across drug and heat

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Disclaimer Statement

1. The views, opinions and/or findings contained in this report are those of the author(s), and should not to be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation.

2. Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

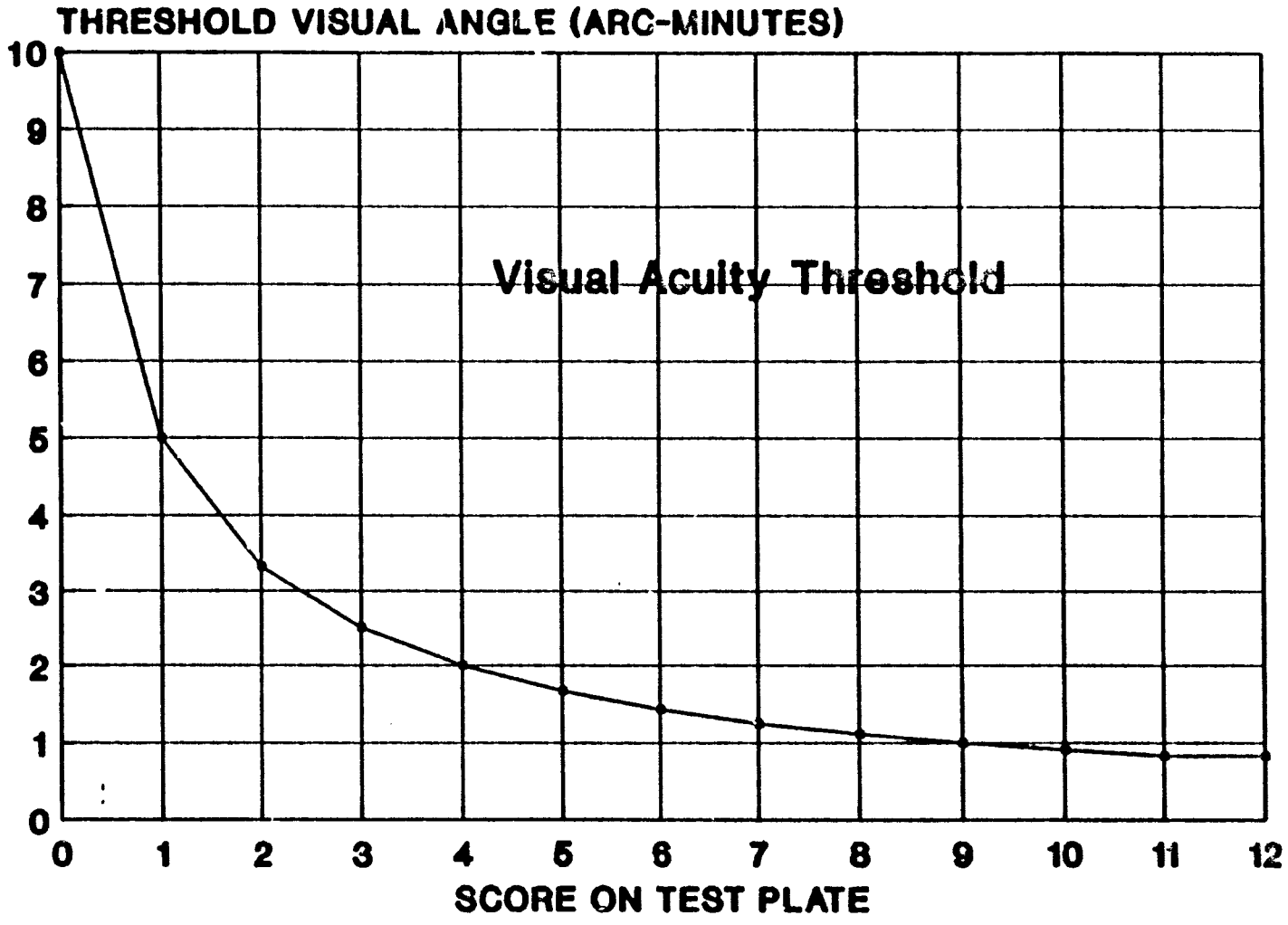
THRESHOLD VISUAL ANGLE (ARC-MINUTES)
10
9
8
7
6
5
4
3
2
1
0
Visual Acuity Threshold
0
1
2
3
4
5
6
7
8
9
10
11
12
SCORE ON TEST PLATE

Figure 1.

CONTRAST SENSITIVITY - DRUG-PLACEBO

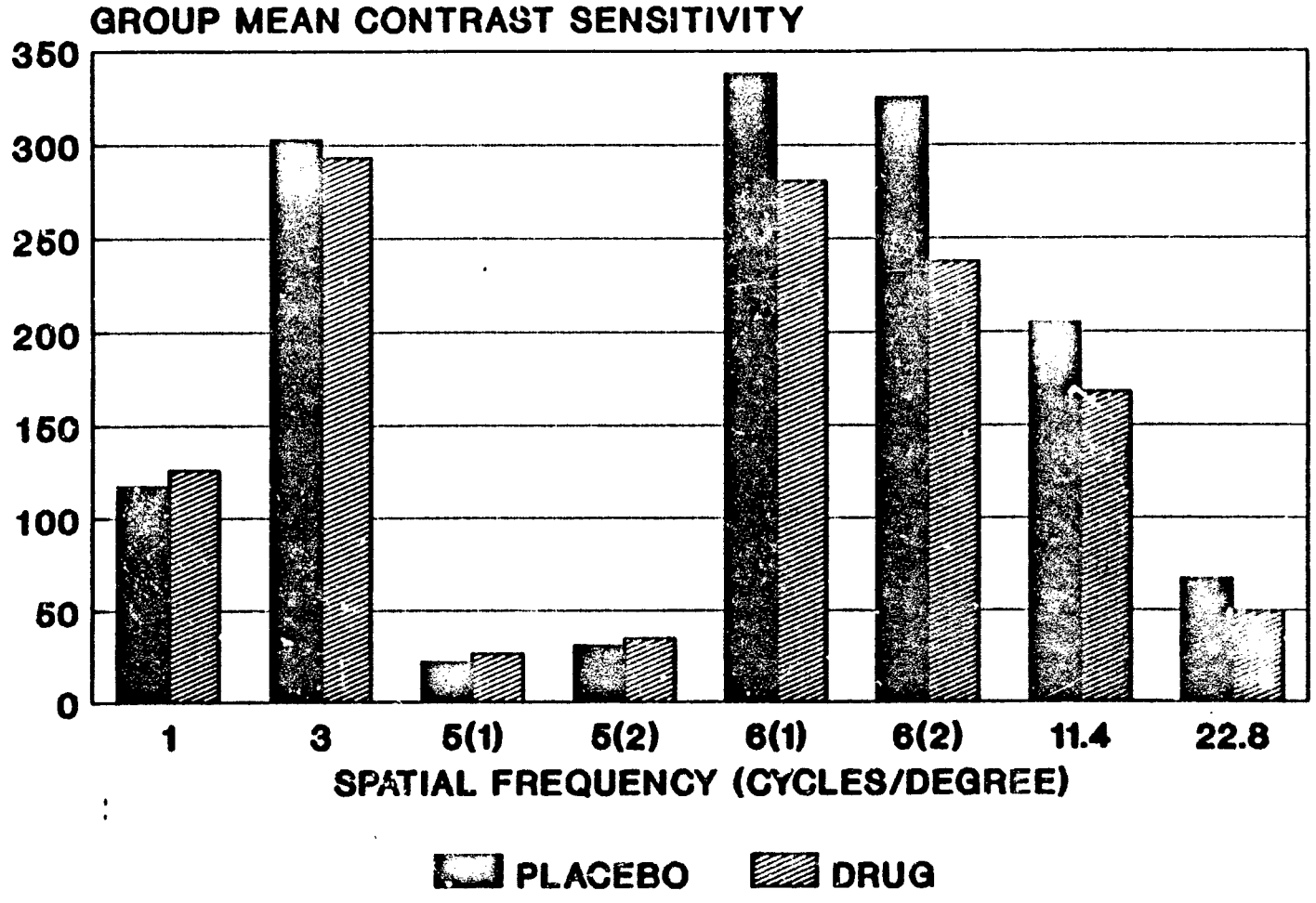

Figure 2.

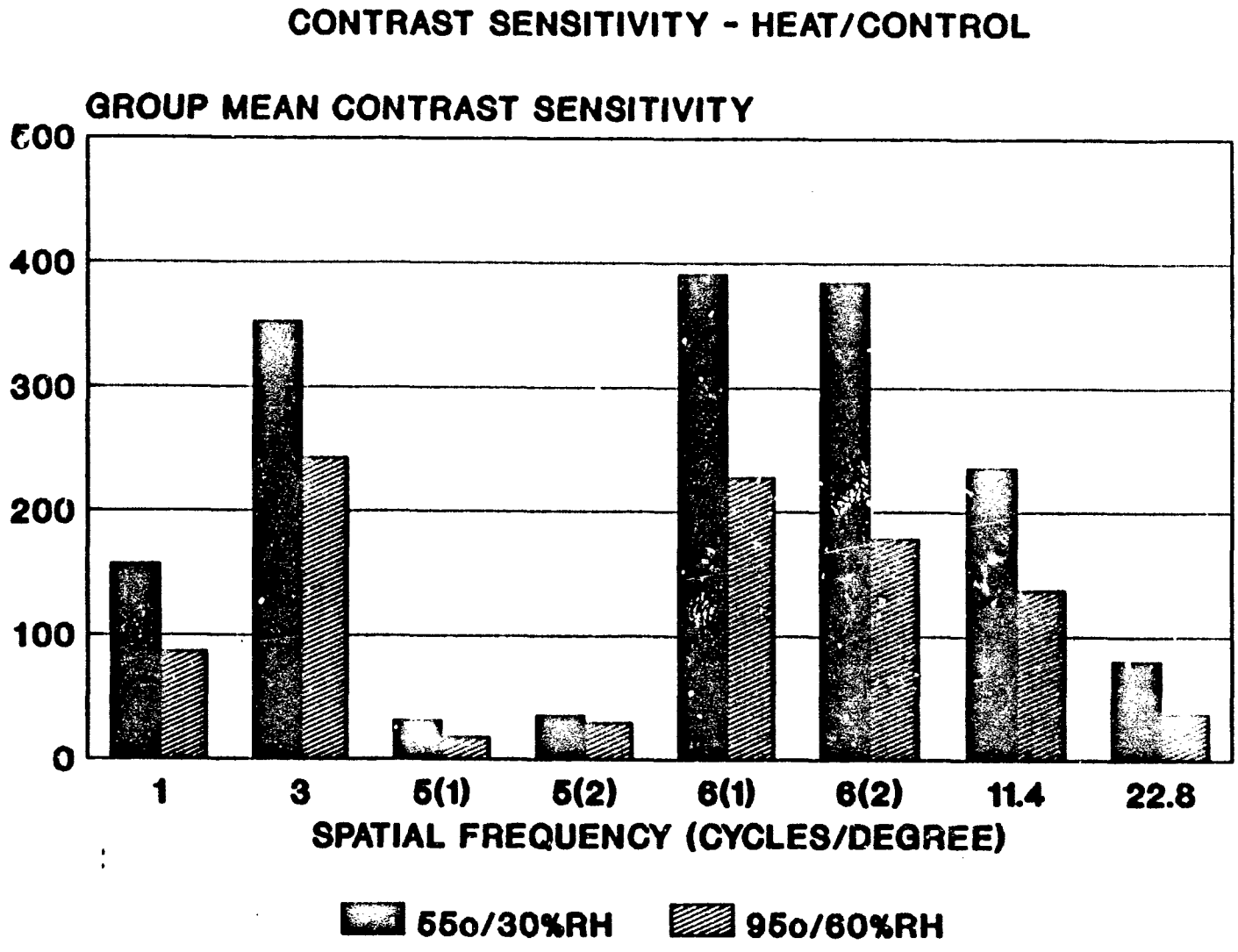
CONTRAST SENSITIVITY - HEAT/CONTROL
GROUP MEAN CONTRAST SENSITIVITY
600
400
300
200
100
0
1
3
5(1)
5(2)
6(1)
6(2)
11.4
22.8
SPATIAL FREQUENCY (CYCLES/DEGREE)
55o/30%RH
95o/60%RH

Fig. 3

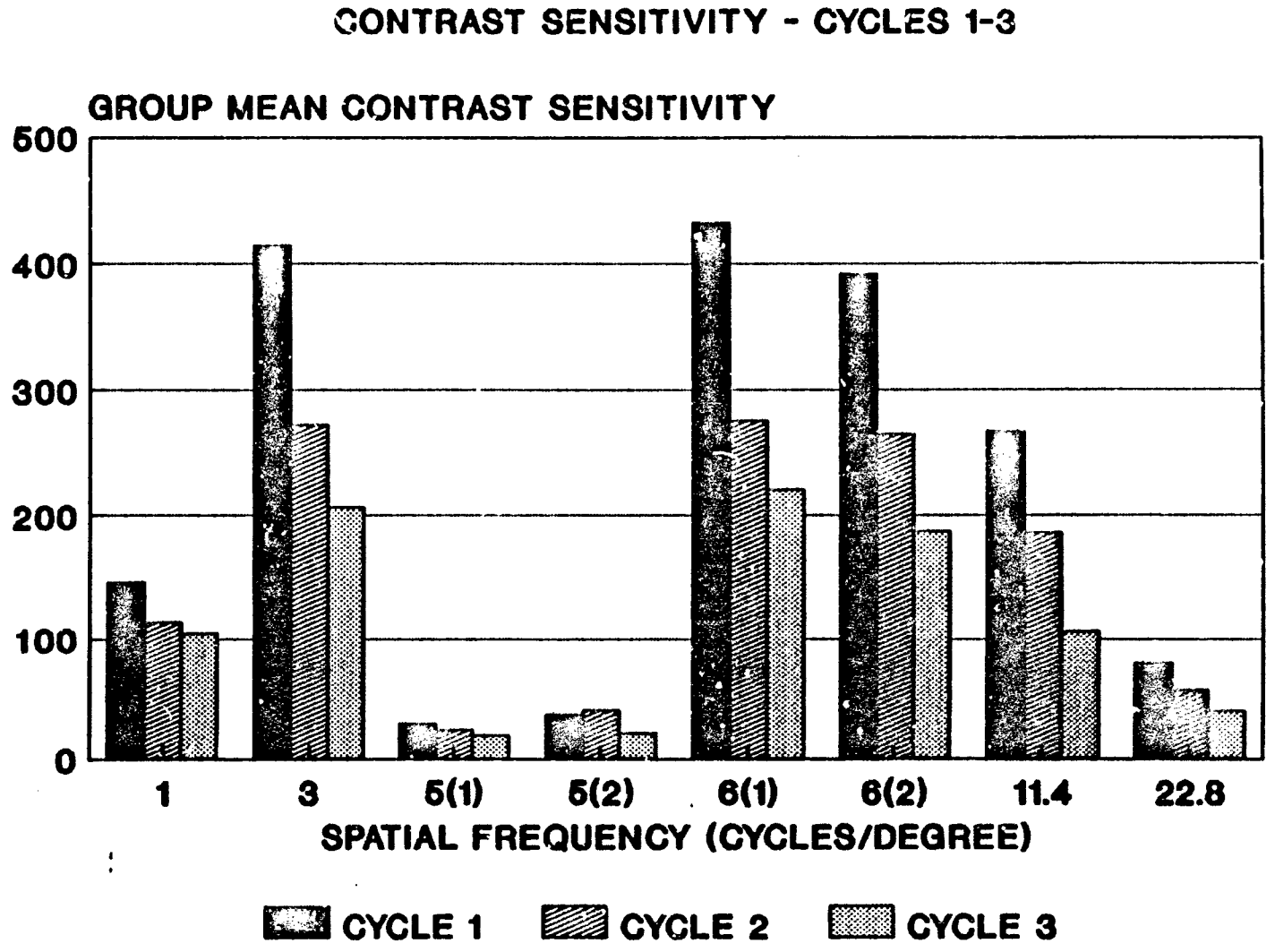
CONTRAST SENSITIVITY - CYCLES 1-3
GROUP MEAN CONTRAST SENSITIVITY
500
400
300
200
100
0
1
3
5(1)
5(2)
6(1)
6(2)
11.4
22.8
SPATIAL FREQUENCY (CYCLES/DEGREE)
CYCLE 1
CYCLE 2
CYCLE 3

Fig. 4